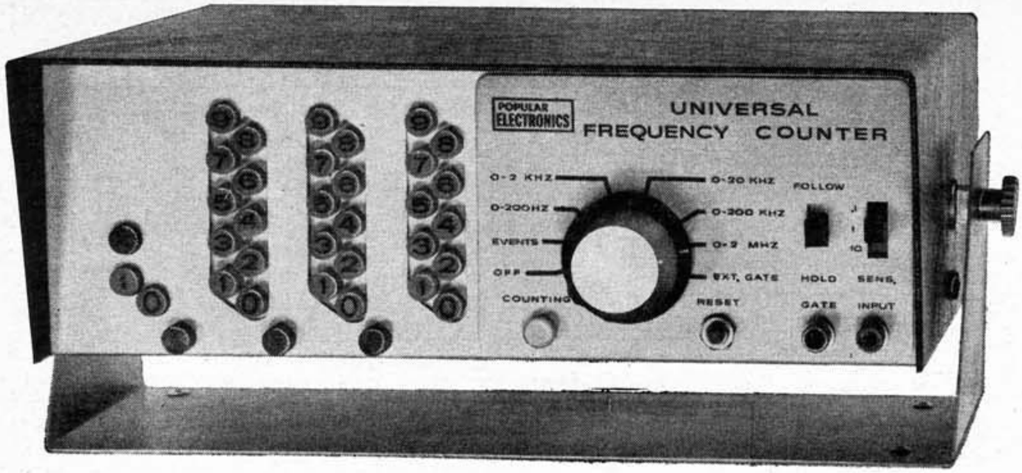


BUILD THE

Popular Electronics Universal Frequency Counter

HIGH-ACCURACY COUNTING TO 2 MHz

BY DON LANCASTER

PART 1 OF 2 PARTS

HOW OFTEN do you come across a frequency counter like this: maximum range—2 MHz; cost—less than $200? The answer is very rarely, and that's why the POPULAR ELECTRONICS Universal Frequency Counter will be of prime interest to project builders in all areas. Its list of attributes doesn't end, however, with frequency range and price: it has seven counting ranges (200 Hz to 2 MHz), a choice of three automatically sequencing time bases (0.1, 1 and 10 seconds), and a comparator with built-in noise immunity and guarded input. The latter provides excellent sensitivity to sine waves, square waves or narrow pulses of either polarity, regardless of duty cycles. A special electronic synchronizer eliminates variations in the display of the last digit (known as bobble) and an overrange light indicates when the counter's capacity is exceeded.

With the Universal Frequency Counter, you can count events, measure frequencies from 0.1 Hz to over 2 MHz or you can gate the instrument externally so that it can be used as a stopwatch or to measure the ratio of two frequencies. The basic instrument has 0.1% accuracy with a 3½-digit display (3 digits plus overrange indication) and a line-operated time base similar to most commercial counters in the "under $600" category.

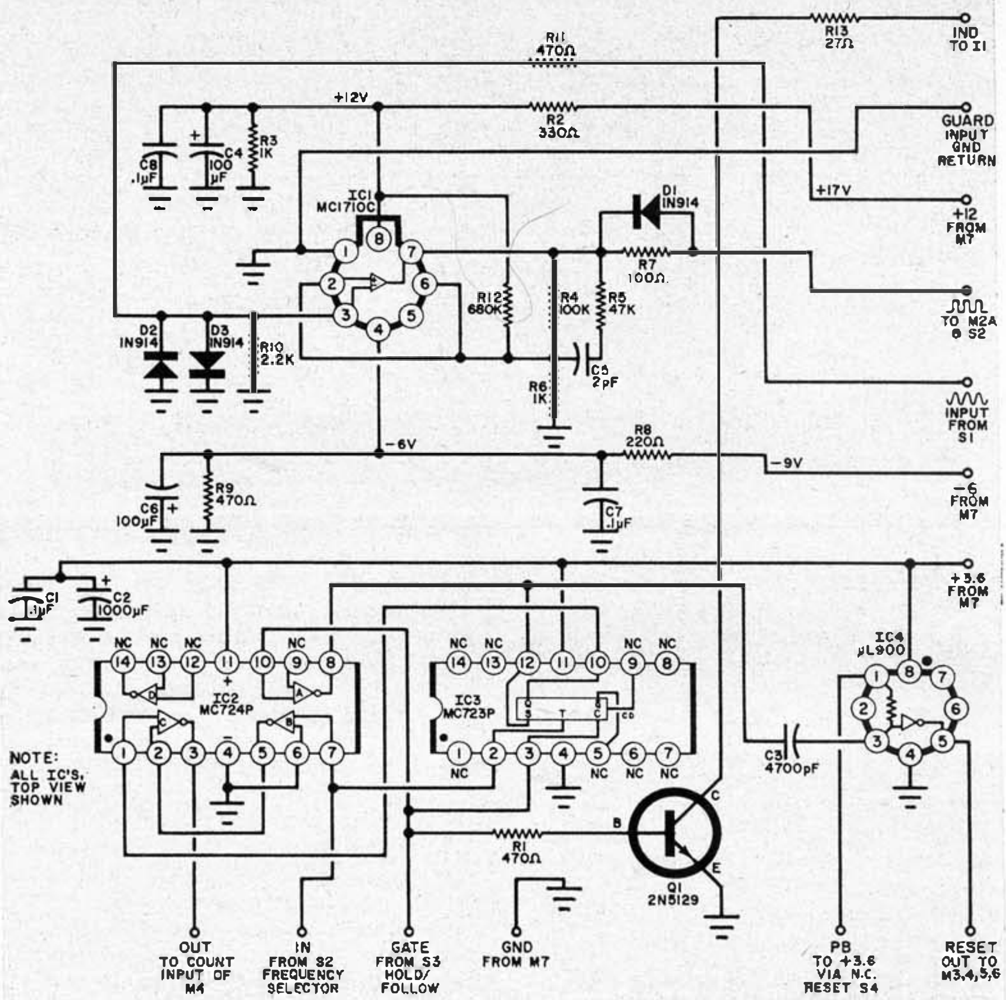


Fig. 1. The comparator module actually contains three separate circuits: input signal comparator (IC1), signal-time base synchronizing circuit (IC2 and IC3), and automatic reset generator IC4.

PARTS LIST
COMPARATOR MODULE

C1, C7, C8—0.1-μF, 10-volt disc ceramic capacitor
C2—1000-μF, 3-volt electrolytic capacitor
C3—4700-pF polystyrene, Mylar, or disc ceramic capacitor
C4, C6—100-μF, 15-volt electrolytic capacitor
C5—2-pF mica capacitor
D1-D3—1N914 silicon computer diode or equivalent
IC1—Operational amplifier (Motorola MC1710CG)
IC2—Quad two-input gate (Motorola MC724P)
IC3—JK flip-flop (Motorola MC723P)
IC4—RTL buffer (Fairchild μL900)
Q1—Transistor (National 2N5129)
R1, R9, R11—470-ohm
R2—330-ohm
R3, R6—1000-ohm
R4—100,000-ohm
R5—47,000-ohm
R7—100-ohm
R8—220-ohm
R10—2200-ohm
R12—680,000-ohm
R13—27-ohm

All resistors ¼-watt

Misc.—PC terminal (USECO 1310B, optional, not provided in kits, 13), #24 wire for jumper, solder.
Note:—The following are available from Southwest Technical Products, Box 16297, San Antonio, Texas 78216: etched and drilled fiberglass circuit board, #M1b, $3.20; complete kit of all parts required, #M-1, $14.65, plus postage, 6 oz.

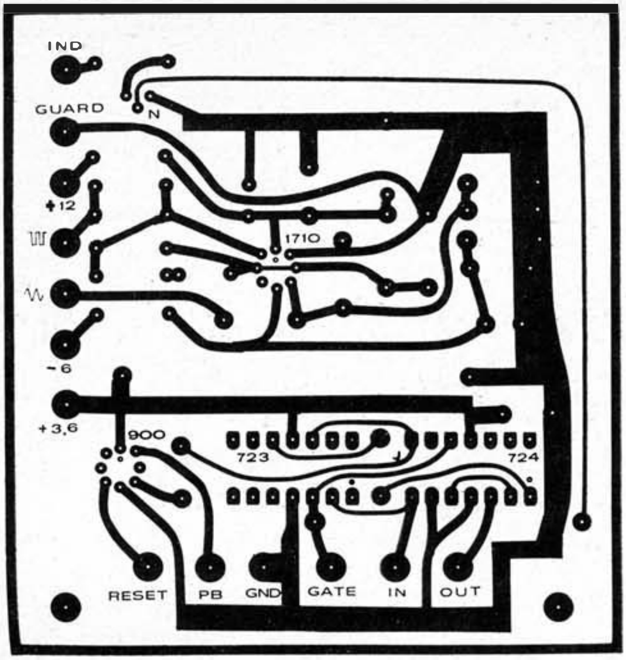


Fig. 2. Actual-size printed board for the comparator module. Because of the complexity of the circuit, printed boards are a must for this project.

Modular construction permits easy addition of extra decades or use of a more accurate, crystal time base. For instance, the time base used in POPULAR ELECTRONICS' Electronic Stopwatch (March 1968) and Sports Timer (October 1968) can be easily adapted for use in the counter. It is also possible to add divide-by-ten scalers to extend the counter's basic range to 20 or 200 MHz, direct reading.

While the Universal Frequency Counter is probably the most complex construction project ever presented in a hobby electronics magazine, the extensive use of integrated circuits and modular construction greatly simplifies the project. It is not a project for beginners but the procedure is relatively simple and straightforward. Parts and a complete kit are readily available as noted in the parts lists.

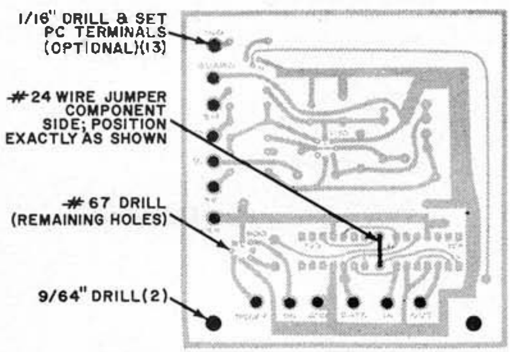


Fig. 3. Drill the board as shown here, and install the single jumper on the component side of board.

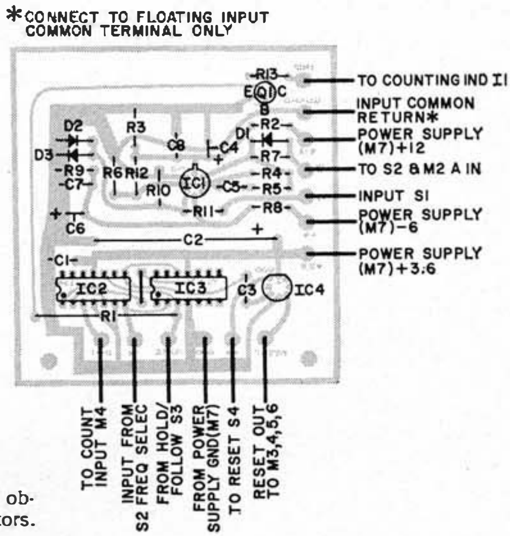


Fig. 4. Install the components taking care to observe polarities of semiconductors and capacitors.

HOW IT WORKS
COMPARATOR MODULE

There are actually three circuits in the Comparator module: a comparator, a synchronizing circuit, and a reset generator.

The comparator (*IC1*) is a high-gain operational amplifier that compares two input signals and provides a digital output signal generated by the difference between the signal input and a reference signal. The reference is derived from the output of the comparator by positive feedback and is either 10 or 30 millivolts positive. When the instantaneous value of the input signal is more than 30 millivolts, the output of the comparator goes to ground, helped along by a dropping reference voltage through positive feedback. If the input signal drops below 10 millivolts, the comparator output goes positive, again aided by feedback. This two-level action is called hysteresis, and it permits the comparator to operate with inputs that are noisy or are very low-frequency sine waves without producing a noisy output.

The comparator is protected on the input side by diodes *D2* and *D3*, which also act to restore the d.c. level for narrow pulse inputs. Feedback is provided by *R4*, *R5*, and *C5* and is both a.c. and d.c. Other components in the comparator circuit provide power supply decoupling and output load matching.

The synchronizing circuit consists of four gates and a JK flip-flop. The circuit delays the input measure command until the first input signal arrives and holds the measure command until one more input signal passes through the switch, *after* the measure command ceases. In this way, the measuring interval is locked to the signal to be counted. This eliminates a one-count bobble that might take place if the measurement command were turned on at random either just before or just after an input signal arrived. Transistor *Q1* is used to drive the COUNTING indicator light.

The reset generator, *IC4*, is a buffer connected as a half-monostable circuit. It generates a 2-microsecond reset pulse at the beginning of the measure command to reset the counters to zero. Operation of the RESET pushbutton, interrupts the positive supply to pin 1 of *IC4* and provides a longer positive output voltage. Either the automatic pulse or the manual reset causes the readouts to drop to zero.

Construction. The Universal Frequency Counter consists of seven modules, plus the case and some panel components. Module 1 is the comparator, module 2 is the Scaler, module 6 is the Gate, and module 7 is the Power Supply. The construction of these modules is given in detail here. Modules 3, 4, and 5 are decimal counting units that are fully described in the Winter 1969 ELECTRONIC EXPERIMENTER'S HANDBOOK and the details of their construction will not be given here.

It is advisable to build each module separately following the instructions carefully. Each module has its own schematic, parts list, and circuit board pattern. Note that round IC's are identified by a tab, flat, or color dot beside pin 8, while the rectangular (inline) units have a notch or dot at one end. In the schematic diagrams, they are shown from the top and the pins are numbered counterclockwise from the identifying mark. Be sure that all IC's are properly positioned before soldering connections. Also be careful to observe the polarities of diodes and electrolytic capacitors. Use fine solder and a low-power (25-35 watts) soldering iron.

Comparator (M1) The schematic for this module is shown in Fig. 1. A printed circuit board is a must. You can make your own, using the foil pattern in Fig. 2 or purchase one etched and drilled (see Parts List for Fig. 1). Install the single jumper on the component side as shown in Fig. 3. To mount the components on the board, follow the layout in Fig. 4.

Scaler (M2) The schematic for the Scaler is shown in Fig. 5. Construction will be greatly simplified by use of the circuit board whose pattern is shown in Fig. 6. Install the 12 jumpers on the component side of the board as shown in Fig. 7. The four jumpers marked with an asterisk should be insulated with small pieces of sleeving. Install the nine IC's and two capacitors as shown in Fig. 8.

Gate (M6) The Gate module schematic is shown in Fig. 9. Once again, construction will be greatly simplified by the use of a PC board. You can make your own using the pattern in Fig. 10. Mount the four jumpers on the component side as

A NOTE ON DCU'S

The Universal Frequency Counter can only use the new, low-power decimal counting units described fully in the Winter 1969 edition of ELECTRONIC EXPERIMENTER'S HANDBOOK. Module kits sold by Southwest Technical Products since October 1968 are of the new type.

Here's how to tell what you have: (1) if your DCU has only three IC's, you have the new unit; (2) if it has four IC's but no 1-watt resistors, you have a medium-power unit, modification of which is suggested but not essential; (3) if it has four IC's and two 1-watt resistors, you have the original version which must be modified if it is to be used in the counter. Modification kits with complete instructions are available from Southwest Technical Products, Box 16297, San Antonio, Texas 78216, for $1 per module.

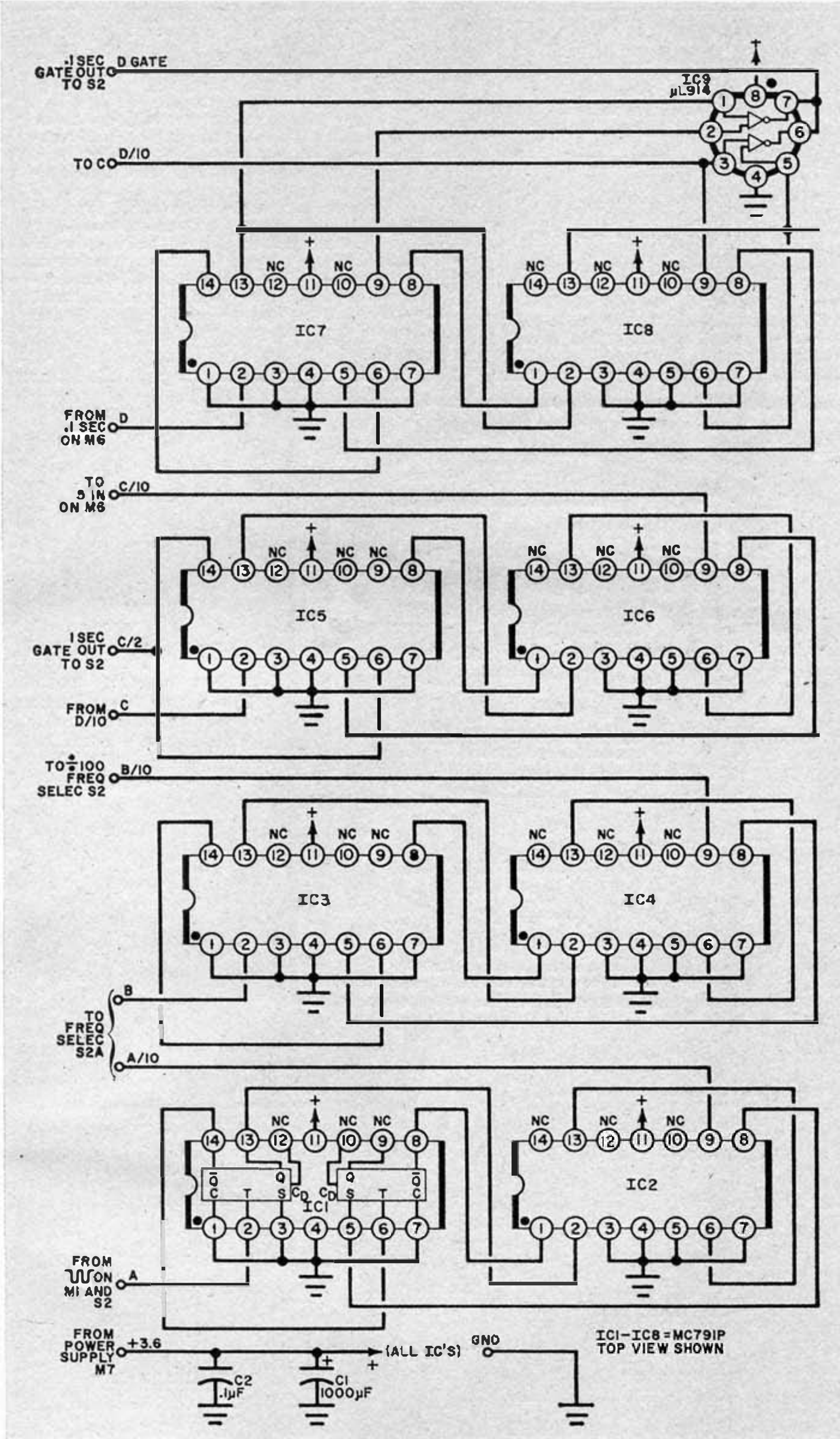


Fig. 5. The scaler module contains four independent divide-by-10 circuits, with IC1-IC4 scaling (divide by 10 or 100) the input frequency, while IC5-IC8 does the same for the timer circuit.

PARTS LIST
SCALER MODULE

C1—1000-µF, 3-volt electrolytic capacitor
C2—0.1-µF, 10-volt disc ceramic capacitor
IC1-IC8—MRTL dual JK flip-flop (Motorola MC791P)
IC9—RTL dual two-input gate (Fairchild µL914)
Misc.—#24 wire (12 jumpers), insulated sleeving for jumpers (4), PC terminals (USECO 1310B, optional, 12, not provided in kit), solder.
Note:—The following are available from Southwest Technical Products, Box 16297, San Antonio, Texas 78216: etched and drilled fiberglass circuit board, #M-2b, $2.85; complete kit of all parts required, #M-2, $21.90, plus postage, 6 oz.

HOW IT WORKS
SCALER MODULE

There are four independent divide-by-ten or decade counters in the Scaler module. Each counter, or scaler, consists of four JK flip-flops in a "modulo-10 minimum-hardware" circuit, the simplest possible decade divider.

Of the four scalers, units A and B are used to divide the input frequency by a factor of 10 or 100 as necessary. Scalers C and D are used in the timing circuit to generate measure commands. Scaler C has a divide-by-two output, which provides the 1-second measure command; scaler D has a 1-of-10 decoder (*IC9*), which provides the 0.1-second measure command.

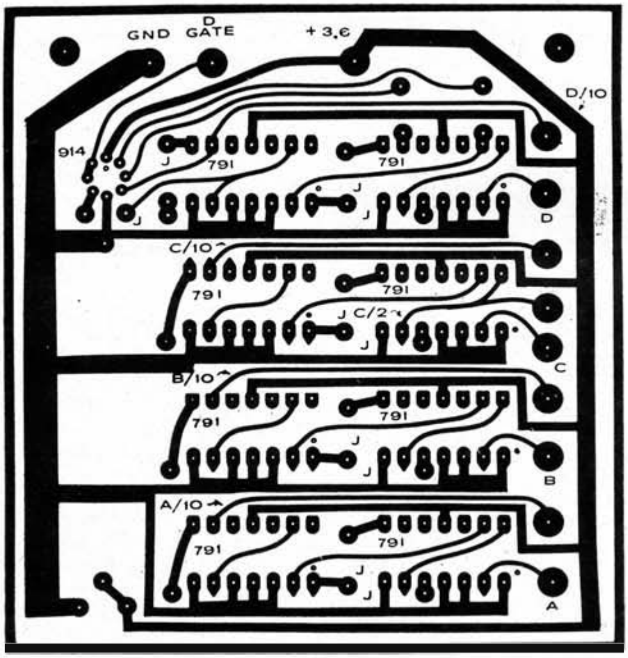


Fig. 6. Actual-size foil pattern for scaler module. This board, like all others is available etched and drilled (see Parts List).

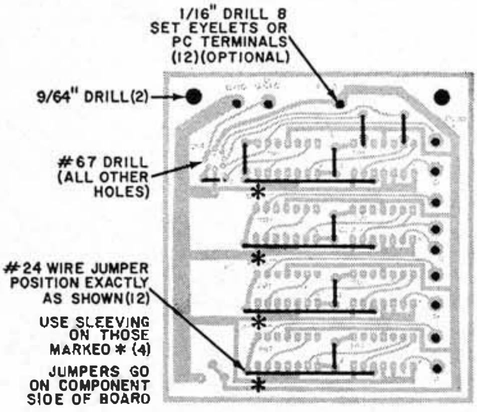


Fig. 7. After drilling the PC board, install the 12 jumpers on the component side in positions shown.

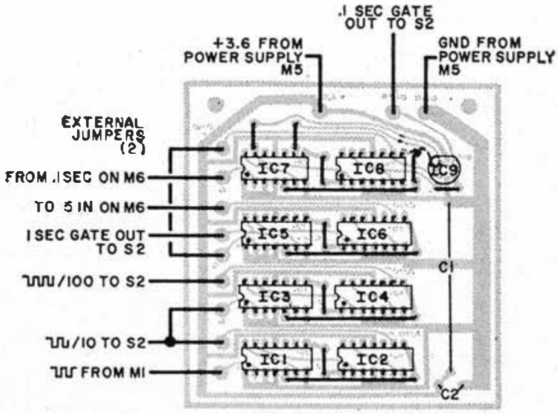


Fig. 8. When installing in-line IC's, observe the notch and code dot. Round IC has a flat at pin 8.

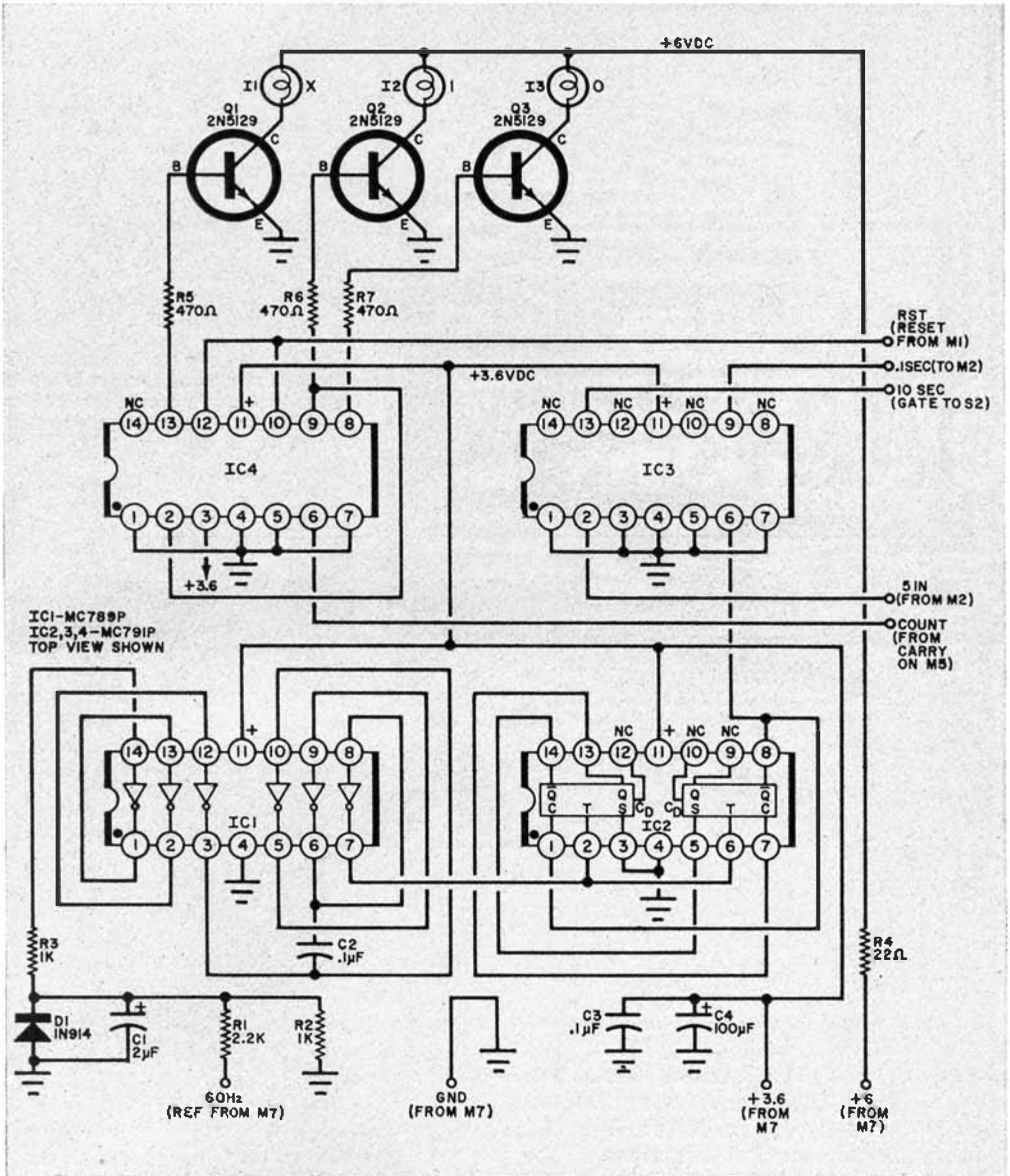


Fig. 9. The gate module performs three functions: accepts, shapes, and converts 60 Hz to 20 Hz; produces .1- and 10-second gates (IC3); and mounts 0-1 and overflow circuit (IC4, Q1, Q2, Q3).

PARTS LIST
GATE MODULE

C1—2-µF, 10-volt electrolytic capacitor
C2, C3—0.1-µF, 10-volt disc ceramic capacitor
C4—100-µF, 15-volt electrolytic capacitor
D1—1N914 silicon computer diode
I1-I3—6.3-volt, 50-mA indicator lamp assembly, two orange, one red (Southwest Technical 0-6.3 and R-6.3, respectively, or similar)
IC1—MRTL hex inverter (Motorola MC789P)
IC2-IC4—MRTL dual JK flip-flop (Motorola MC791P)
Q1-Q3—Transistor (National 2N5129)
R1—2200-ohm
R2, R3—1000-ohm
R4—22-ohm
R5-R7—470-ohm
(All resistors ¼-watt)
Misc.—#24 wire (4 jumpers), insulated sleeving (1 inch), bracket and mounting hardware for lamps, PC terminals (USECO 1310B, optional, 9, not provided in kit), solder.
Note:—The following are available from Southwest Technical Products, Box 16297, San Antonio, Texas 78216: etched and drilled circuit board, #M-6b, $2.35; complete kit of all parts required, #M-6, $13.85, plus postage, 5 oz.

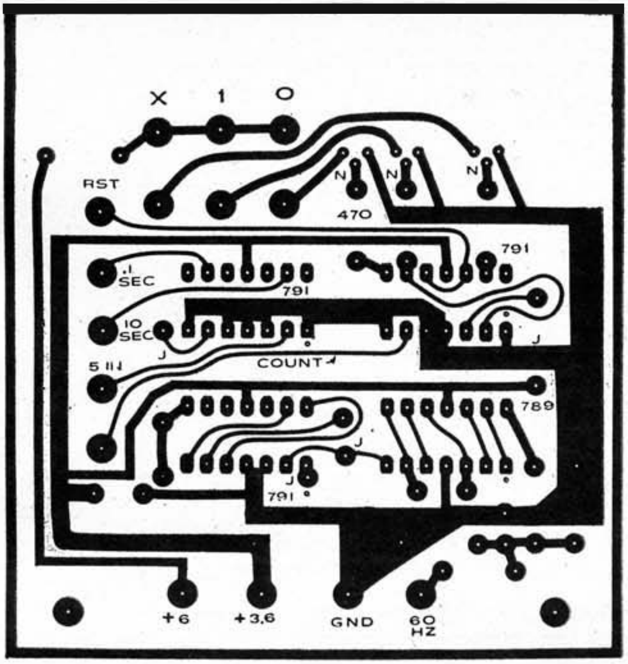


Fig. 10. Actual-size foil pattern for the gate module. As in the other foil patterns, each input-output termination and semiconductors are marked.

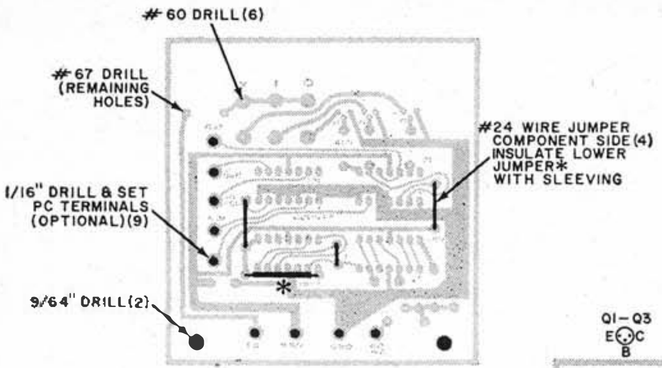


Fig. 11. Mount four jumpers on the component side of the board, making sure the indicated jumper is insulated to prevent short circuiting IC2.

shown in Fig. 11. Insulate the lower jumper with suitable sleeving. Mount the components as shown in Fig. 12.

A mounting bracket is required for this module to hold the three indicator lights. Details for this part appear in "Low-Cost Counting Unit," ELECTRONIC EXPERIMENTER'S HANDBOOK, Winter 1969 and "Digital Volt-Ohmmeter," POPULAR ELECTRONICS, December 1968. The bracket is mounted by match drilling to the PC board, then pop-riveting using #4 hardware. An orange plastic lens can be used for both the 0 and 1 indicators and a red lens for the overrange indicator.

Power Supply (M7) Most of the power supply, whose schematic is shown in Fig. 13, is assembled on the PC board shown

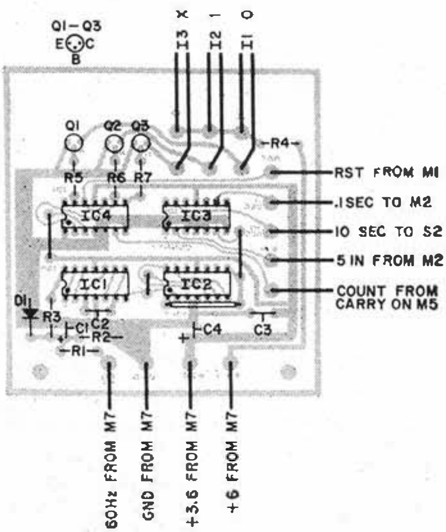


Fig. 12. Mount the board components as shown here, once again taking care to observe all polarities.

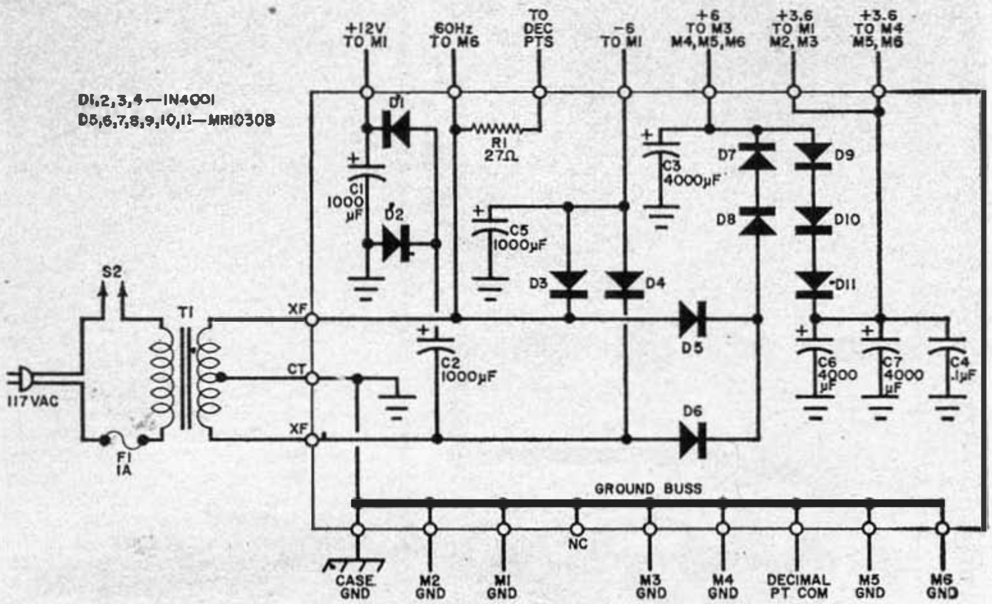


Fig. 13. Note the eight connections to the ground buss. This is done to reduce stray coupling between the various modules. Each module ground should be run on a short, heavy lead.

PARTS LIST
POWER SUPPLY MODULE

C1, C2, C5—1000-µF, 25-volt electrolytic capacitor
C3, C6, C7—4000-µF, 6-volt electrolytic capacitor
C4—0.1-µF, 10-volt disc ceramic capacitor
D1-D4—1-ampere, 50-PIV silicon diode, 1N4001 or equivalent
D5-D11—3-ampere average, 24-ampere peak, 50-PIV silicon rectifier (Motorola MR1030B, do not substitute)
F1—1-ampere fuse
R1—27-ohm, ¼-watt carbon resistor
T1—12.6-volt center-tapped, 2-ampere filament transformer
Misc.—PC mouting spacers and hardware, PC terminals (USECO 1310B, optional, 19, not provided in kit), line cord with strain relief, fuse-holder and mounting hardware, solder.
Note:—The following are available from Southwest Technical Products, Box 16297, San Antonio, Texas 78216: etched and drilled fiberglass circuit board, #M-7b, $3.50; complete kit of all parts required, #M-7, $19.10 plus postage, 3 lb.

HOW IT WORKS
GATE MODULE

The Gate module contains three circuits: the gate generator, the 10-second measure command generator, and the 0-1 counter and overflow latch with indicators. The first two circuits, together with scalers C and D in the Scaler module, provide the time base, while the last circuit extends the range of the counter by half a digit and provides an indication to call attention to the fact that the input signal has exceeded the full counter capacity.

The gate generator accepts the 60-Hz power-line reference from the power supply module, filters and clamps it, and then applies it to a hex-inverter squaring circuit, *IC1*. Positive feedback, via *C2*, provides additional edge steepening, to provide the 100-nanosecond rise and fall times required by the next stage.

A divide-by-three counter (*IC2*) uses a pair of flip-flops to reduce the 60-Hz input to a 20-Hz square wave. This circuit is twisted slightly from a "normal" divide-by-three circuit to save some PC board jumpers. The first flip-flop in *IC3* divides the 20-Hz time-base signal into 10 Hz (a 0.1-sec period) which is the reference required to run scalers C and D on the Scaler module. The second flip-flop converts the output of scaler C which has a 10-sec period into a 10-sec on and 10-sec off measure command as required for the 0-200-Hz range.

The 0-1 counter and overrange latch is made up of *IC4* driving transistors *Q1* through *Q3*, which supply power to the appropriate front-panel indicator lamps.

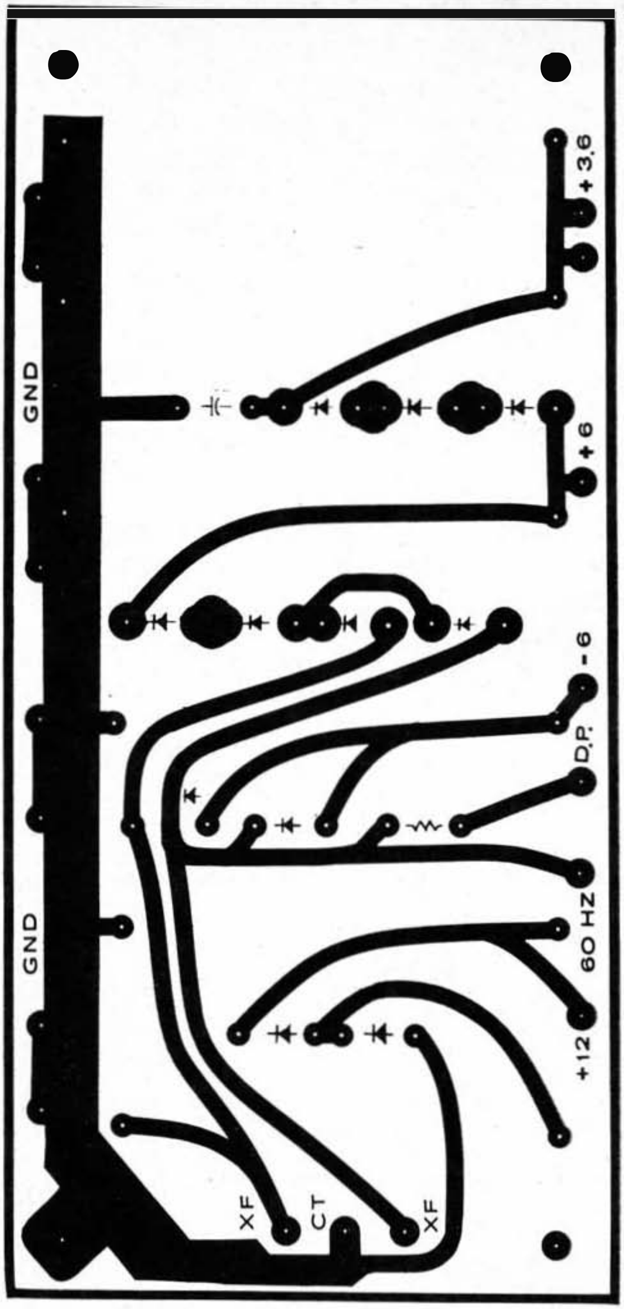


Fig. 14. Power supply foil pattern is the largest one in the instrument. It should be made on fiberglass to avoid heat damage from power diodes. To assist cooling, mount all diodes slightly off the board to allow cool air to circulate around them to dissipate the heat. Also, do not allow the diodes to touch the capacitors.

in Fig. 14. The power transformer (*T1*) and the fuse (*F1*) are mounted on the counter chassis. Use a G-10 fiberglass base for this circuit board so that it can withstand the heat generated by the power diodes. Drill holes as shown in Fig. 15.

To avoid stray coupling between modules through ground connections, it is very important that all module grounds be isolated from each other and at very low impedance. For this reason, a wide ground buss is provided on the power supply circuit board, with a separate terminal for connections to each of the other modules. A separate #16 (or other heavy-gauge) wire should be run from each module to the ground buss. All

HOW IT WORKS
POWER SUPPLY

The power supply must provide more than an ampere of current at 3.6 volts d.c. and other lower current supplies at +6, −6, and +12 volts. It also provides a.c. to the decimal point lamp and the Gate module.

To obtain all these voltages from a single power transformer requires a few more diodes than would normally be needed with a multi-winding transformer.

The +12-volt supply is derived from a voltage doubler consisting of *D1*, *D2*, *C1*, and *C2*. The supply is actually about 17 volts at the output terminal; it is reduced to 12 volts by the decoupling network in the Comparator module. Similarly the full-wave rectifier made up of *D3*, *D4*, and *C5* provides about −9 volts, which is reduced to −6 volts in the Comparator.

A second full-wave rectifier (*D5* and *D6*) produces +6 volts with diodes *D7* and *D8* acting as a dynamic regulator. This supply is reduced by *D9*, *D10*, and *D11* to provide +3.6 volts for the integrated circuits. While the average current through diodes *D5* through *D11* is about one ampere, the peak current is much larger—high enough to damage ordinary silicon power diodes. That is why three-ampere silicon rectifiers are specified in the Parts List.

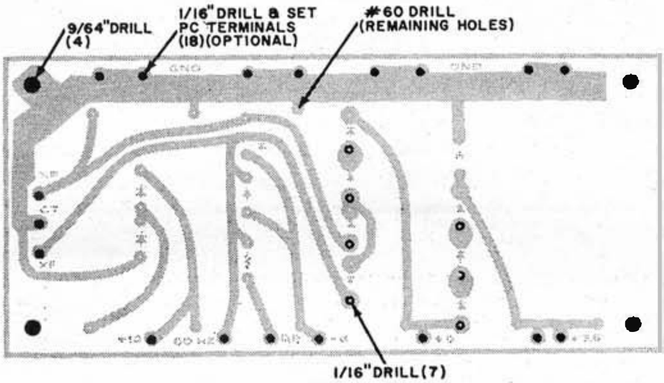


Fig. 15. There are no jumpers on the power supply board. After it is drilled, mount the components.

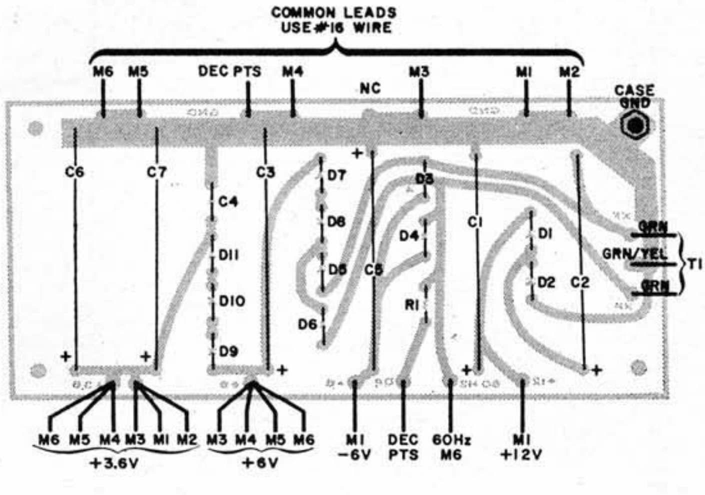


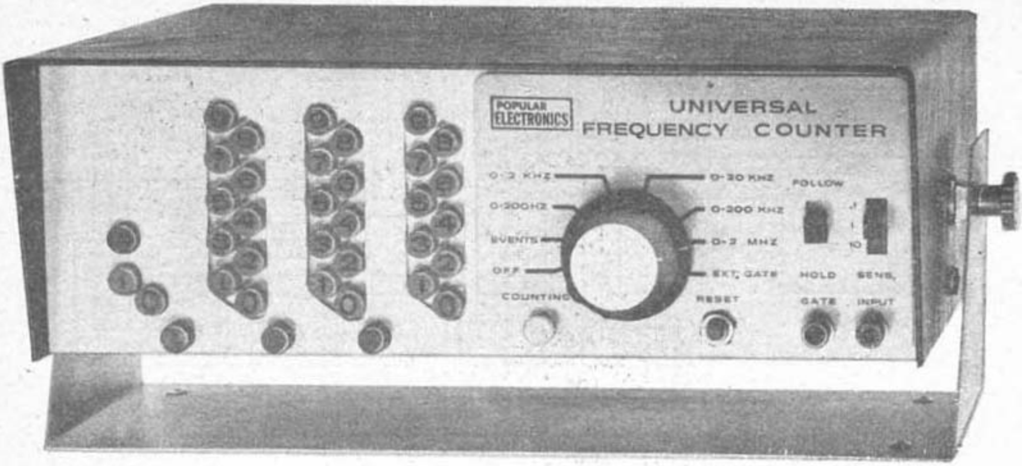
Fig. 16. Finish the power supply by mounting the components. Note that each module ground is made via an independent #16 gauge wire and one connection is made to counter case (upper right).

ground leads should be kept as short as possible.

Components are installed on the power supply board as shown in Fig. 16. Note that *C5* is upside down with respect to the polarity of the other capacitors. Note also that all diodes point in the same direction. Be sure that there is sufficient cooling space between the diodes and the electrolytic capacitors since the latter can be damaged by diode heat generation.

Connect the power supply module to the case through a single ground lead. Do not run any other ground leads to the chassis except the return for *J1*, the INPUT jack.

NOTE: Final assembly, alignment, and calibration will be given next month.



Popular Electronics Universal Frequency Counter

BY DON LANCASTER

Part 2

Note: *Construction of modules for the Counter appeared in the March issue.*

Assembly of Complete Unit. The circuit for the overall counter is shown in Fig. 17, while Fig. 18 shows the interior of the chassis. The vinyl-clad case that comes with the complete kit is punched and machined, and includes assembly instructions. If you select another type of enclosure, use Fig. 18 as a general layout guide. An optional dialplate (see Parts List for Fig. 17) adds a professional touch and also serves as a front-panel layout template.

Modules *M1* through *M6* are arranged in a line along the front of the case, supported by brackets similar to those used on the "Digital Volt-Ohmmeter" (POPULAR ELECTRONICS, December 1968). The three decimal-point indicator lamps are placed between the decade units as shown in the photo, while the Power Supply module (*M7*) mounts on the rear wall of the chassis with spacers and #6 hardware. The fuse (*F1*) and power transformer (*T1*) are mounted on the bottom of the chassis.

Note that the frame of input jack *J2* is isolated (insulated) from chassis ground and has an independent ground lead, called a "guard," running directly to the *M1* board. This lead is very important since it prevents any internally generated ground noise from interfering with the input. Use nylon washers to insulate the jack from the chassis.

Don't forget the individual ground leads from each module to the power

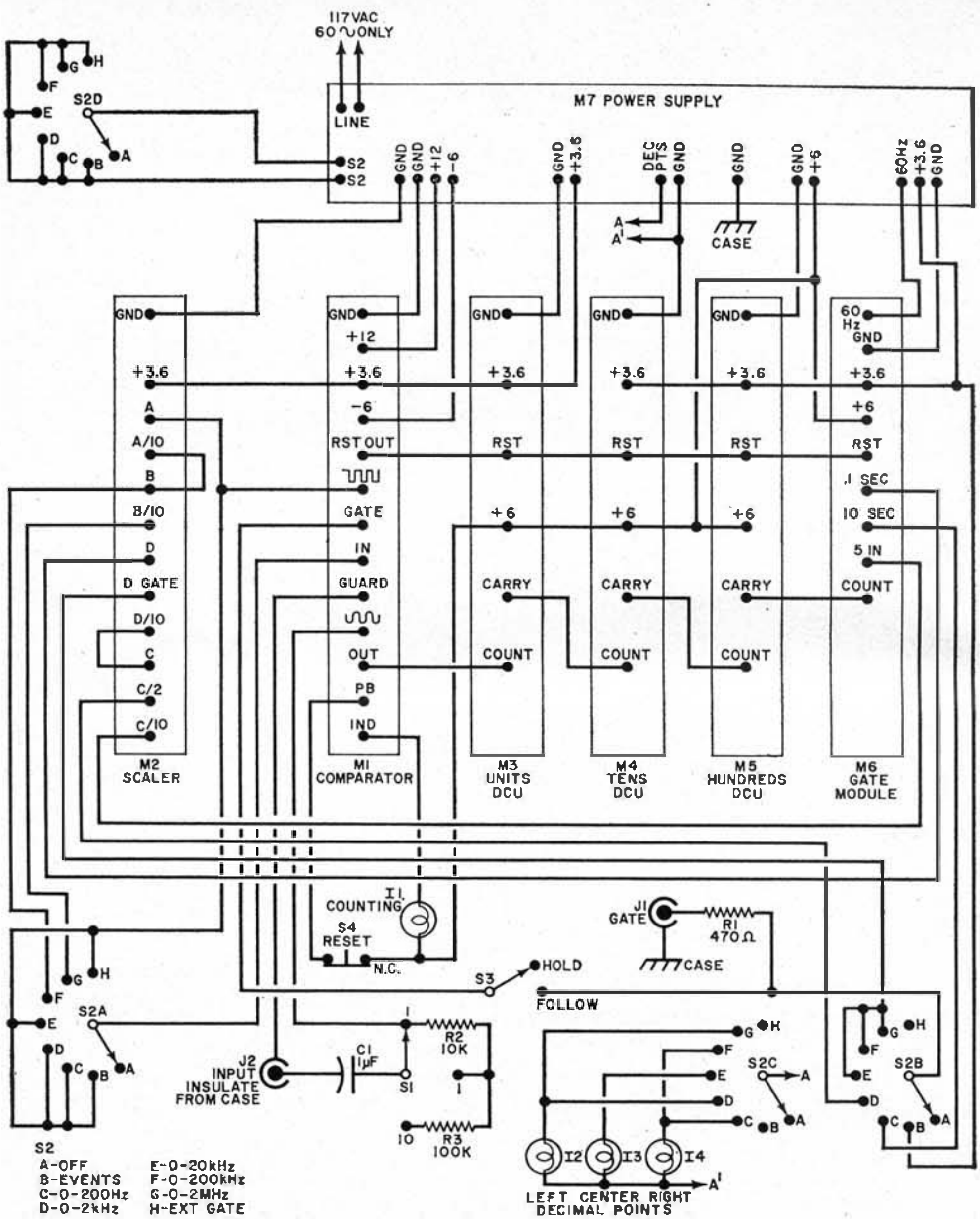


Fig. 17. Interconnections for complete frequency counter. Signal input jack J2 is insulated from chassis to prevent internal noise interference with the input signal.

supply ground buss.

The main selector switch (*S2*) has four decks, one of which is isolated from the other three by spacers. The isolated deck controls the 117-volt, 60-Hz power, while the other three (starting from the front) select the frequency, the timing, and the decimal point.

Preliminary Checkout and Operation. The frequency counter requires no calibration and has no internal adjustments. It is only as accurate as the 117-volt a.c. power-line stability and display resolution permit it to be. The following tests can be performed to check the general assembly for proper operation.

PARTS LIST COMPLETE COUNTER

C1—1-µF, 400-volt Mylar capacitor
I1-I4—6.3-volt, 50-mA pilot lamp and lens assembly, three green, one white (Southwest Technical G-6.3 and W-6.3, respectively or similar)
J1—Phono jack
J2—Phono jack and nylon insulated mounting kit
M1—Comparator module
M2—Scaler module
M3-M5—DCU module (see text)
M6—Gate module
M7—Power supply module
R1—470-ohm, ¼-watt resistor
R2—10,000-ohm, ¼-watt resistor
R3—100,000-ohm, ¼-watt resistor
S1—Three-position, single-pole slide switch
S2—Four-deck, four-pole, eight-position, nonshorting miniature selector switch. Close space first three decks, isolate fourth with ¼" spacers. (Southwest Technical SW111S1 or equivalent)
S3—S.p.s.t. slide switch
S4—S.p.s.t. normally closed pushbutton switch
Misc.—5" x 5½" x 10" vinyl-clad, prepunched case and support assembly, dialplate, 1½-inch knob, mounting brackets for modules, mechanical hardware, #16 wire for grounds, #22 hookup wire, solder.*
**Anodized dialplate available from Reill's Photo Finishing, 4627 N. 11th St., Phoenix, Arizona 85014; in black and silver $3.00; red, gold, or copper $3.45, postpaid in USA.*
Note:—Complete kit of parts to build counter including case but not dialplate is available from Southwest Technical Products, Box 16297, San Antonio, Texas 78216. Order # 165C, $120, plus postage, 7 lb.

HOW IT WORKS COMPLETE COUNTER

The frequency to be counted is applied to the sensitivity control, which reduces the inbut level by 1 or 10 to the approximately 100 millivolts required for normal operation. The signal is then sent to the Comparator module (*M1*) where it is converted from a sine wave to a square wave of the same frequency with sharp rise and fall times. Any noise that might be present in the input is also rejected in the Comparator. The Comparator output is fed directly to the range selector switch *S2* and also to a pair of decade scalers that provides divide-by-ten and divide-by-one-hundred outputs. The latter are also connected to the range selector switch.

The output of the Comparator (f) is selected for the EVENTS function, 0-200 Hz, 0-2 kHz, 0-20 kHz and for the external gate (EXT. GATE) operation. The output from the first decade scaler (f/10) is used for the 0-200 Hz position, and the output of the second scaler (f/100) is used for the 0-2 MHz position.

The time base starts with a 60-Hz reference from the power supply. This signal is filtered, squared, and divided by six (all in module *M6*) to obtain the 0.1-second gating reference. Two divisions by ten produce the 1-second and 10-second time references. These time intervals, along with a positive voltage for EVENTS and no input for EXT. GATE are routed to the range selector switch.

From the selector switch, the time commands go through the HOLD-FOLLOW switch which permits a choice of automatically updating the reading or holding the last reading.

Both the measure command and the selected input frequency go through the synchronizing circuit in the Comparator module. The measure command turns the electronic switch on and off, but it does it in such a way that only whole cycles of the input frequency are counted. This eliminates the one-digit bobble in the counting. The time-base gated frequency then goes to the counting and display circuits.

The counter can be reset to zero at any time by operation of the manual RESET pushbutton, but in normal modes of operation, the counters are automatically reset just before a new count begins.

The operation of the counter is fully automatic. The available measure commands are 10-s measure and 10-s display for 0-200-Hz operation; 1-s measure and 1-s display for 0-2-kHz operation; and 0.1-s measure and 0.9-s display for the other ranges. To keep the display on longer, flip switch S3 to HOLD.

Plug the counter into a source of 117-volt 60-Hz power and place selector switch *S2* on EVENTS and switch *S3* on FOLLOW. One, or possibly two, numerals in each decade should be illuminated. Momentarily depressing the RESET button should immediately produce a 0000 reading.

Check all supply voltages, particularly the +6 and +3.6 volts, to be sure that they are within 0.1 volt of their correct values. The −6 and +12-volt supplies should be checked at their respective terminals on *IC1* of the Comparator module *M1*.

Place the range selector switch on the 0-200 Hz position and observe the COUNTING light on the front panel. It should cycle on for 10 seconds and off for 10 seconds. Place the selector switch on 0-2 kHz. The COUNTING light should now cycle on for 1 second and off for 1 second. With the selector switch on any higher range, the light should flash on for 0.1 second, once each second.

To check the operation of the decimal-point indicators, place the range selector switch on the 0-2 MHz position and note that the left decimal point indicator is illuminated. For other switch positions, lights should be on as follows: 0-200 kHz, right; 0-20 kHz, center; 0-2 kHz, left; 0-200 Hz, right.

With the counter still energized, set the FOLLOW-HOLD switch to FOLLOW, the range switch to 0-2 kHz, and the SENS. (sensitivity) switch to .1. Insert a test lead in the INPUT jack and touch the other end of the test lead. Note that the counter starts operating erratically only when the COUNTING light is lit. The

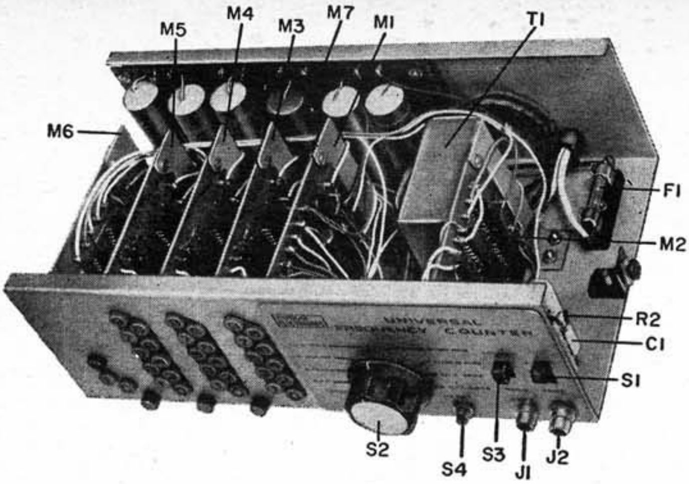


Fig. 18. Author's prototype may be duplicated or used as a guide. Because of the length of M7, the Power Supply module, it is mounted along the rear apron of the chassis. When using a different physical layout, remember that the Power Supply generates some heat and mount it out of the way where it will not affect the heat-sensitive components that are mounted on the other modules.

display should last only as long as the COUNTING light is dark. The counting units should start to count at the same instant that the COUNTING light comes back on. Placing the SENS. switch on either the 1 or 10 position should stop the counting operation.

If the counter passes all of these tests, it is probably working properly and is ready for use. As a final check, and to gain some experience in using the counter, use a bounceless pushbutton circuit (described in "Low-Cost Counting Unit," POPULAR ELECTRONICS, February 1968, or ELECTRONIC EXPERIMENTER'S HANDBOOK, Winter 1969) and a low-frequency audio oscillator. When using the counter, always start with the SENS. switch down to the 1 or .1 position as required to get a stable reading. Also, do not forget that an input lead (whether it is coaxial cable or phono lead) that is too long will attenuate (and load) a high-frequency signal.

Key Waveforms. The following information can be used if trouble is experienced in getting the counter to operate properly. The waveforms at various points in the circuit vary depending on switch settings and the nature of the input. However, there are some critical points at which the waveforms can be checked to determine whether the counter is working properly.

Comparator (M1) When sufficient input signal is applied, the output at the square-wave terminal of this module (connected to *D1* and *R7*) should be either a square or a rectangular wave from 0 to 2.4 volts positive. The output goes positive when the instantaneous input signal drops below +10 mV and drops to zero when the input exceeds +30 mV. The rise and fall times of this waveform should be about 60 nanoseconds.

The feedback to pin 2 of *IC1* should show a steep leading edge that reaches +80 mV, followed by a rapid decay (about 90 ns) to the +30 mV level. The trailing edge of this waveform should have a rapid transition to −40 mV and a rapid decay back to +10 mV. This signal is present only when an input signal is applied to the counter. Because of the very fast switching of this waveform, you will have to use a high-quality, lab-type oscilloscope to make exact measurements although the basic signal can be seen on a conventional service scope.

The synchronizing circuit in the Comparator can be tested by using a bounceless pushbutton and observing the DCU's and the COUNTING indicator light, in the 0-200-Hz range. The first count after the COUNTING light comes on should not be counted, and the first DCU should display starting at the second count. The first count after the COUNTING light goes off should be counted and the display should remain steady after that. Correct operation of this circuit guarantees that the device will only count whole input cycles.

Scaler (M2) The input to the A scaler should be identical to the square-wave output observed on the Comparator.

Output A/10 should be a rectangular

wave with a frequency 1/10 that of the input. It should be about 1.8 volts in amplitude and have a 6:4 duty cycle. This, of course, is also the input to the B scaler.

COUNTER SPECIFICATIONS

Function: Measuring frequency, events, events-per-unit-time, or the ratio of two frequencies. it is also a source of precision 0.1-, 1-, and 10-second timing signals.

Ranges: 0-200 Hz, 0-2 kHz, 0-20 kHz, 0-200 kHz, 0-2 MHz, events, and externally gated events or ratio.

Accuracy: Power-line stability plus or minus one-half count. Typical accuracy is 0.1%.

Resolution: One part in 2000 to full scale. 0.1 Hz on 0-200-Hz scale.

Sensitivity: Switch adjustable from nominal 0.1, 1, or 10 volts. For sine waves—30 mV r.m.s. from 50 Hz to 3 MHz; 300 mV r.m.s. from 5 to 50 Hz. For pulses—symmetric pulse, 100 mV p-p; narrow positive pulse, 50 mV p-p; narrow negative pulse, 700 mV p-p.

Input conditioning: Automatically provided for all but mechanical contacts. High-gain IC comparator provides snap action, 10-mV noise offset, and 20-mV hysteresis. Any reasonable wave shape is acceptable, including sine or square waves, or rectangular pulses of either polarity.

Input protection: D.c. blocking to 200 volts. Combination dual-diode limiter and d.c. restorer allows safe measurement in practically all test situations.

Input impedance: 10-volt range, 112,000 ohms; 1-volt range, 12,500 ohms; 0.1-volt range, 2500 ohms. Typical shunting capacity is less than 30 pF.

Gating: Fully synchronized master gate used to eliminate the one-count ambiguity associated with older counter designs. Last digit is constant rather than bobbling between two values.

Display: Switch selects hold or follow. Infinite display in hold function, automatic updating in follow. For 0-200 Hz, 10-second measure, 10-second display; for 0-2 kHz, 1-second measure, 1-second display; for higher frequencies, 0.1-second measure, 0.9-second display.

Miscellaneous: Automatic overrange indicator comes on when full-scale count is exceeded. Floating decimal points. Manual reset and override. Time gate outputs available at gate terminal during measurement. Modular construction adaptable to crystal time base for higher accuracy. Extendable with input scaling to 0-20 MHz or 0-200 MHz. All solid-state circuit uses 26 IC's, 43 transistors, and 14 diodes.

The frequency of output B/10 should be 1/10 that of A/10 and 1/100 that of the input to the A scaler. Its amplitude depends on the setting of the range selector switch, but it should range between 1.8 and 3.6 volts, positive. It should have a 6:4 duty cycle and rise and fall times of about 50 ns.

The GATE terminal of the D scaler should have a repeating waveform that goes positive about 2 volts for 0.1 second and to ground for 0.9 second.

The output at C/2 should be a repeating signal that is positive for 1 second and ground for 1 second, with an amplitude of about 2 volts.

The output at C/10 should be a repeating symmetrical square wave with a frequency of 0.2 Hz (5-second period), with an amplitude of about 2 volts, positive.

Gate (M6) There should be a clean 60-Hz sine wave at the junction of *D1* and *R3* on this module (terminal 60 Hz). It should be offset with the negative peak at −0.7 volts and the positive at +2.4 volts.

At pin 7 of *IC1* there should be a 60-Hz rectangular wave having 50-ns rise and fall times and an amplitude of about +2 volts. The output at pin 8 of *IC2* should be a 20-Hz rectangular wave with a 1:2 duty cycle and a 2-volt positive amplitude.

The 0.1 SEC output of this module should be a symmetrical, positive-going wave at 0.1 second, with 50-ns rise and fall times. The 10 SEC output should be positive for 10 seconds and ground for 10 seconds.

Reset. The reset buss (RST on all modules except *M2*) is at ground most of the time. Depressing the front panel RESET switch should raise the level of the buss to about 1.6 volts and all DCU's should promptly return to a zero indication. Also during normal operation, there is, on the reset buss, a brief pulse, about 2 microseconds long and 1.6 volts in amplitude, immediately after the leading positive edge of the selected time gate. This waveform erases the old counter indications and drops them to zero the instant a new measurement is to begin. This waveform can be seen best on a lab-type oscilloscope having both triggered sweep and vertical channel delay. —30—